

Ultra-Wideband Time-Difference-Of-Arrival Two-Point-Tracking System

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Outline

- ✱ Motivation
- ✱ TDOA Tracking Methodology
- ✱ Analytical Tracking Resolution
- ✱ Fine Time Resolution of UWB Pulses
- ✱ Lab Tests of the Prototype System
- ✱ Summary
- ✱ Future Work

Motivation

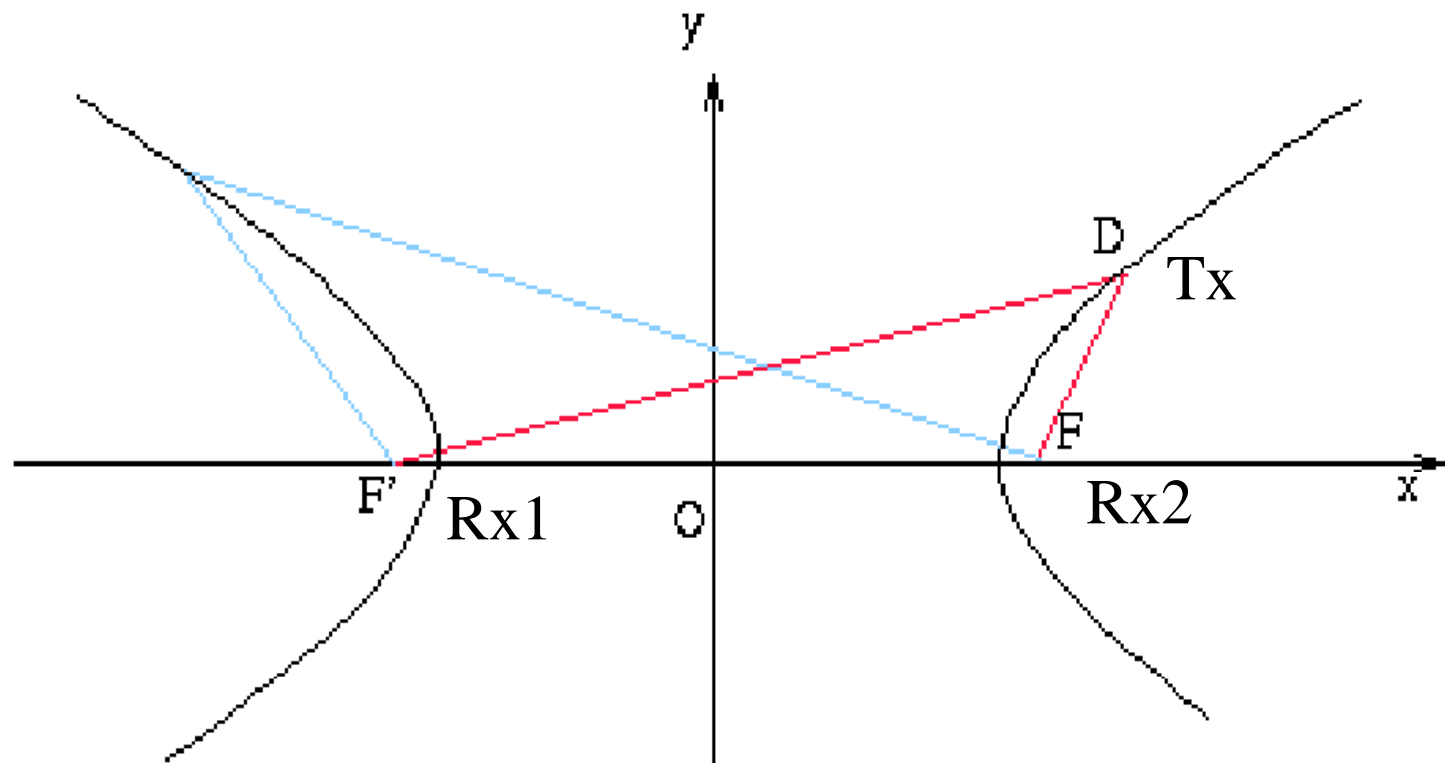
- ✧ UWB TDOA high resolution proximity Tracking System (developed at JSC) provides sub-inch tracking resolution for Honeywell's robotic control system [1].
- ✧ This system can be enhanced with two-point-tracking capability and applied to the docking process of the Lunar rover Chariot for the battery charging.



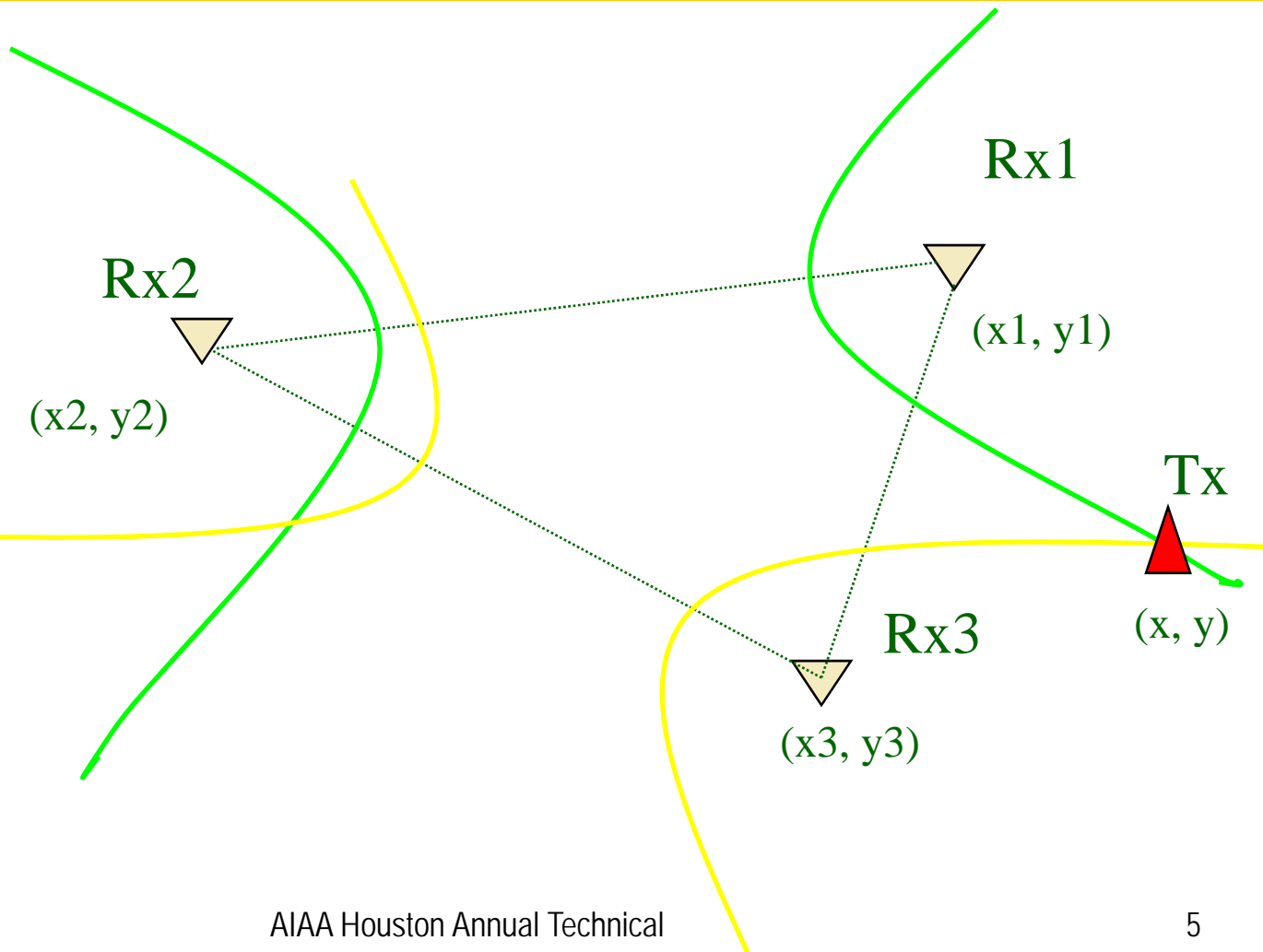
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Time Difference of Arrival (TDOA)

Hyperbola: $b^2 x^2 - a^2 y^2 = a^2 b^2$



Time Difference of Arrival (TDOA)

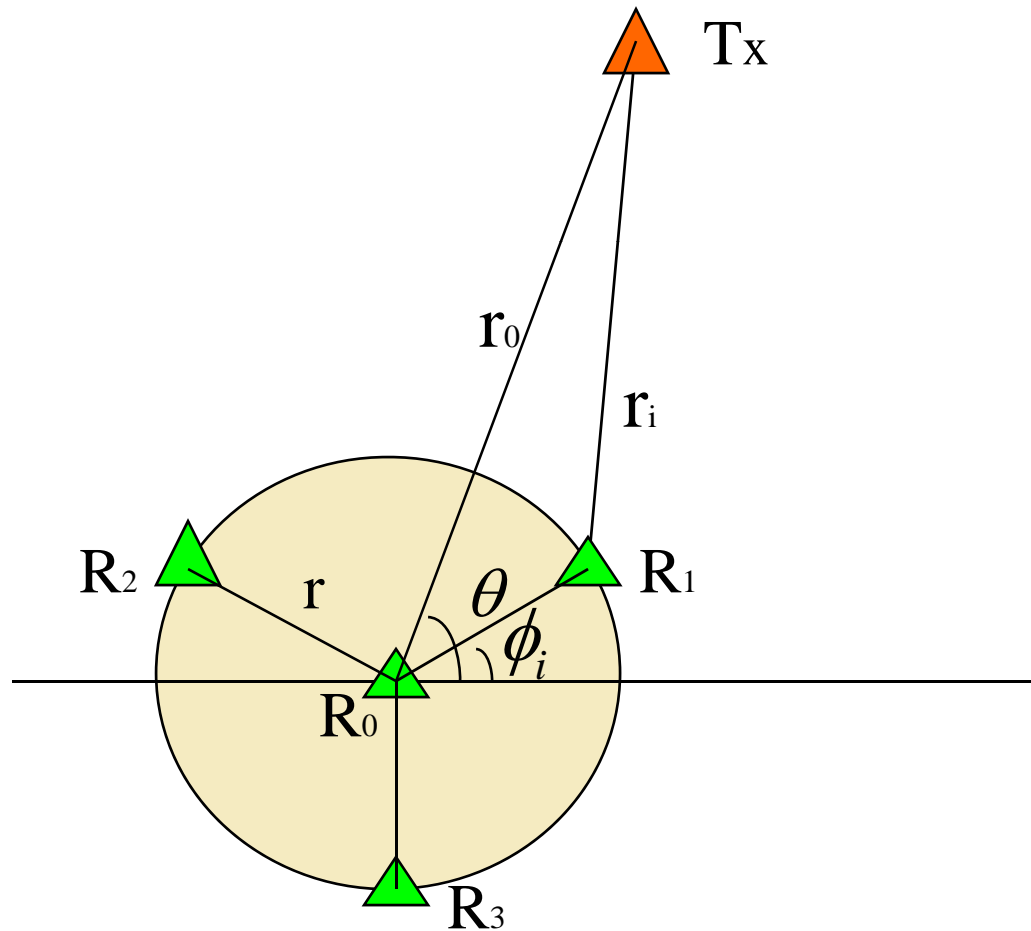




Advantages of TDOA

- ✦ No synchronization between Tx and Rx
- ✦ Simplex (one-way) data estimation
- ✦ TDOA estimates can be obtained through Cross-Correlation plus Peak Detection (CCPD)

Resolution Analysis (setting)



Proximity High Resolution [1]

$$\text{MSE} \approx 4c^2\sigma^2$$

$$\bar{\varepsilon} = 2c\sigma$$

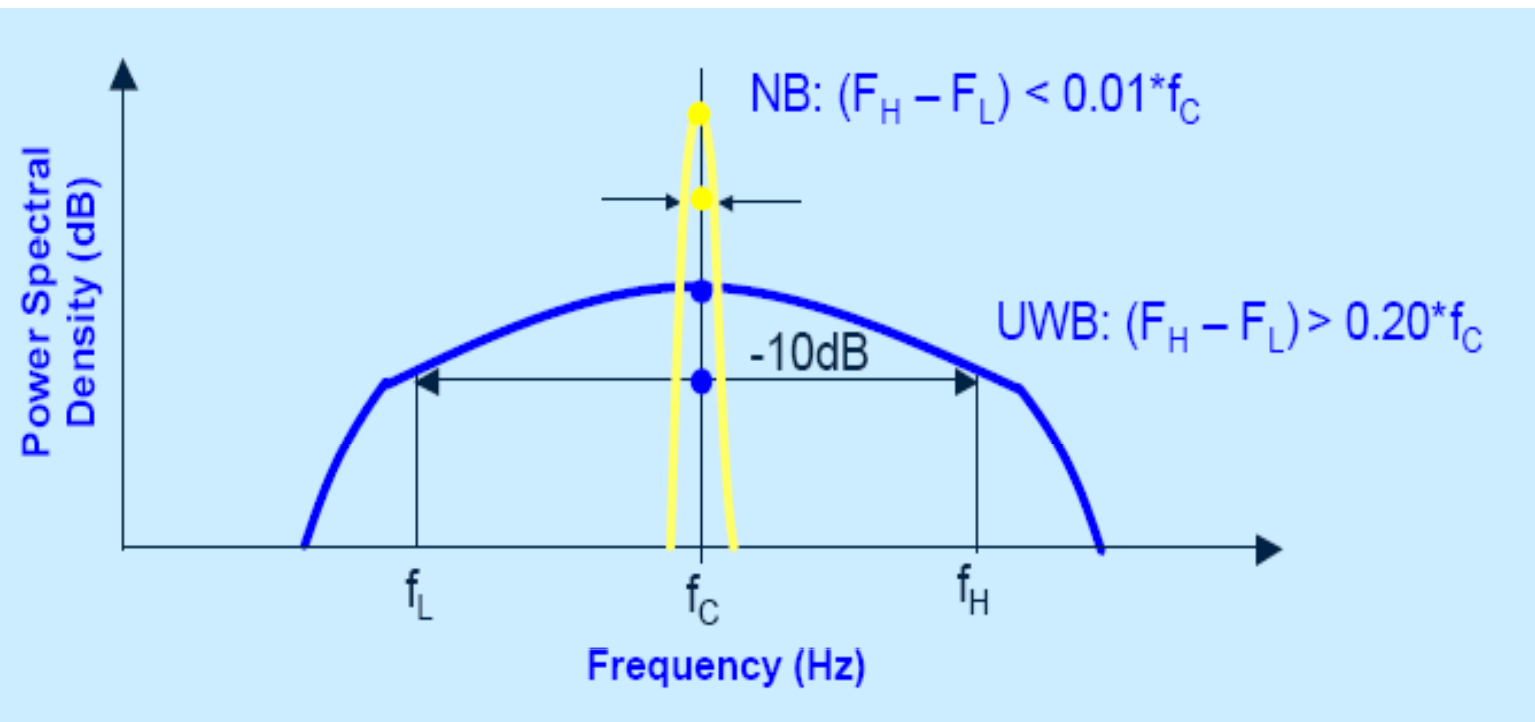
$$c = 3 \times 10^8 \text{ m/s}$$

$$\sigma = 10^{-9} \text{ s} = 1 \text{ ns}, \quad \bar{\varepsilon} = 0.6 \text{ m}$$

$$\sigma = 10^{-11} \text{ s} = 10 \text{ ps}, \quad \bar{\varepsilon} = 0.006 \text{ m}$$

What is UWB ? (FCC Definition)

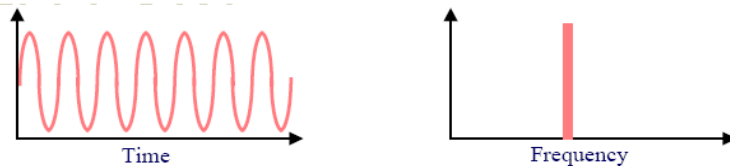
A ultra wideband device is defined as any device where the fractional bandwidth is **greater than 0.20** or occupies **500 MHz or more** of spectrum.



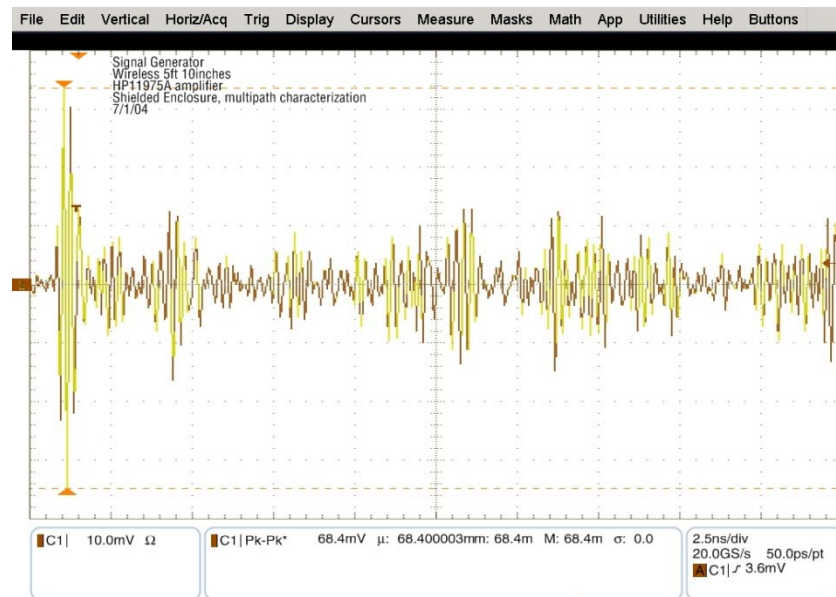
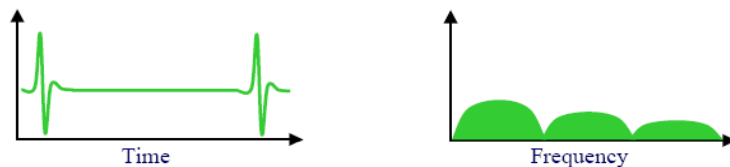
Why UWB ?

- Immunity to interference from narrow band RF systems due to ultra-wide bandwidth
- Low impact on other RF systems due to extremely low power spectral densities
- Capable of precise tracking due to sub-nanosecond time resolution
- Robust performance in multipath environments
- High data rate communication (100 Mbps and higher)

Sinusoidal, Narrowband



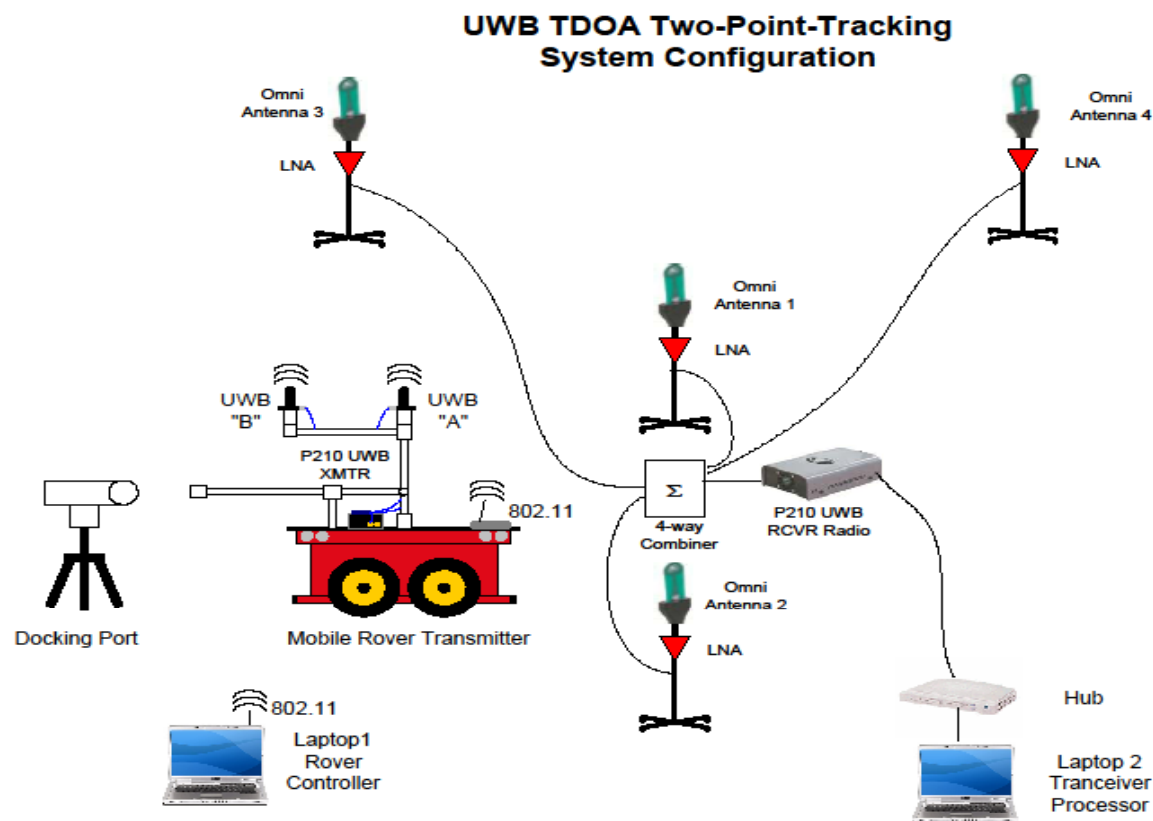
Impulse, Ultra-Wideband



2009-05-15 UWB Fine Time Resolution

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Resolving between direct vs. multipath components is possible with extremely narrow UWB pulses

System Configuration



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TDOA Proximity Tracking (1Rx4A set-up)

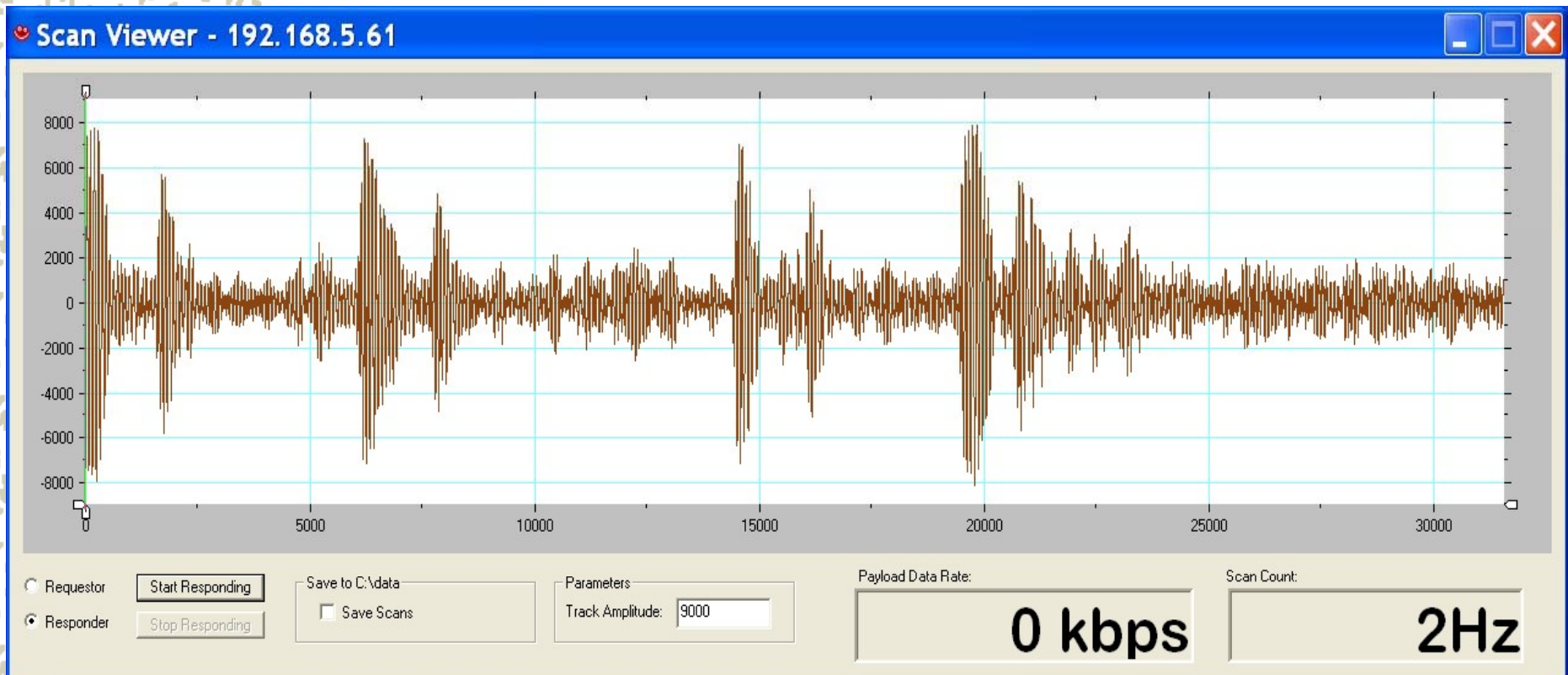


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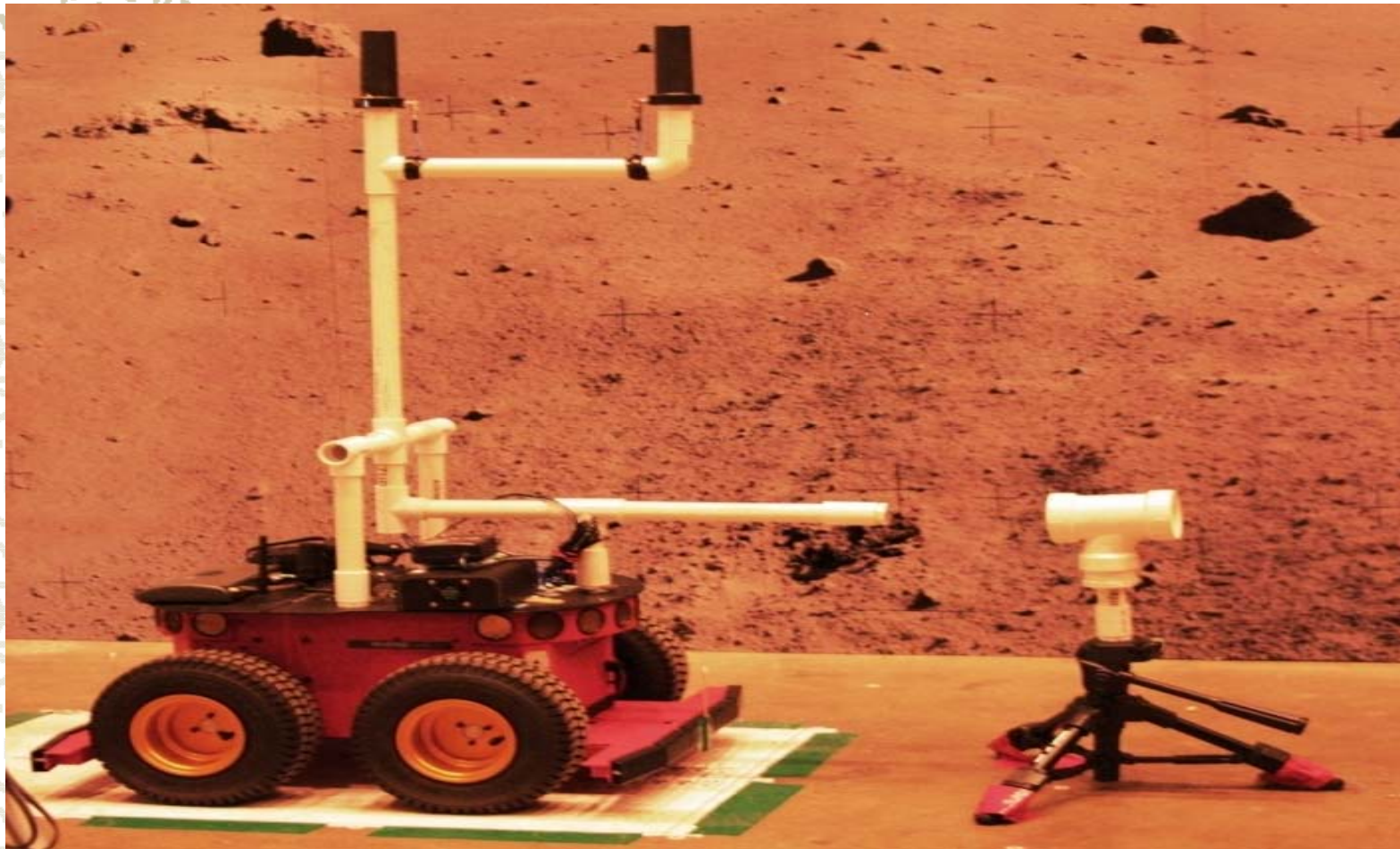
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TDOA Estimate (from 8 pulses)



Docking Process Guided by Two-Point-Tracking



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Summary

- ✱ A UWB TDOA Two-Point-Tracking System has been conceived and developed at JSC.
- ✱ This system can provide sub-inch tracking capability of two points on one target.
- ✱ This capability can be applied to guide a docking process in a 2D space.
- ✱ Lab tests demonstrate the feasibility of this technology.



Future Work

- ✦ Future work includes expanding the tracking area to the size of Chariot docking site and test the docking process with the actual dimension of the Chariot battery charging station.



References

- ✱ [1]. Jianjun (David) Ni; "UWB TDOA Proximity High Resolution Tracking System", IEEE Symposium for Space Applications of Wireless & RFID (SWIRF), Houston, TX, May 2007.